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Status of the Atlantic salmon (*Salmo Salar* L.) Stocks of Lomond River, Torrent River and Western Arm Brook, Newfoundland, 1999

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ABSTRACT

Returns of small salmon to Lomond River were 42% higher than in 1998 and 8% higher than the 1992-98 mean. Returns of large salmon were the third highest on record and 46% higher than the 1992-98 mean. Returns of small salmon to Torrent River were 19% less than in 1998 and 10% lower than the 1992-98 mean. Returns of large salmon in 1999 were 46% less than in 1998 and 13% less than the 1992-98 mean. Returns of small salmon to Western Arm Brook were 39% less than in 1998 but 10% higher than the 1992-98 mean. Returns of large salmon were 82% less than in 1998 and 50% less than the 1992-98 mean. Returns of both small and large salmon to all three rivers were higher than the 1984-91 means indicating improvements in the stocks since the commercial salmon fishery moratorium. The proportion of large salmon was higher than the 1984-91 mean on all three rivers. It is highly unlikely that the conservation requirement was not achieved on any of the three rivers in 1999. On the basis of the smolt production at Western Arm Brook in 1999 returns of 1SW salmon in 2000 are expected to be lower than in 1999 and the 1992-98 mean provided marine survival remains the same. Marine survival of smolts to returning 1SW salmon at Western Arm Brook was 6.1% in 1999, more than twice that in 1997. Spawning escapements are expected to exceed conservation requirements on all three rivers in 2000 assuming marine survival remains the same as in 1999. A decline in marine survival similar to that, which occurred in 1997, would mean that conservation requirements would likely not be achieved on Western Arm Brook in 2000. Due to overall improvements in stocks and the added control afforded by the river classification system, there may be opportunities on these rivers for increased harvests below counting facilities. However, given the uncertainty in annual marine survival observed for Western Arm Brook it is cautioned that harvests on this river should not be permitted until the conservation requirement (300 salmon) has been achieved. Expansion of fisheries above counting facilities on all three selected rivers is not recommended unless angling catches can be an accurately determined.

RÉSUMÉ

Les remontes de petits saumons dans Lomond River étaient de 42 % plus élevées qu'en 1998 et 8 % supérieures à la moyenne de 1992-1998. Les remontes de gros saumons étaient les troisièmes plus fortes enregistrées et étaient 46 % plus élevées que la moyenne de 1992-98. Les remontes de petits saumons dans Torrent River étaient 19 % moins élevés qu'en 1998, et 10 % plus faibles que la moyenne pour 1992-1998. Celles de gros saumons en 1999 étaient 46 % moins élevé qu'en 1998 et 13 % moins élevées que la moyenne de 1992-98. Les remontes de petits saumons dans Western Arm Brook étaient de 39 % plus faibles que la moyenne pour 1998 mais 10 % plus élevé que la moyenne pour 1992-98. Celles de gros saumons étaient 82 % moins élevés qu'en 1998 et 50 % plus faibles que la moyenne pour 1992-98. Les remontes de petits et de gros saumons dans les trois cours d'eau étaient plus élevés que les moyennes pour 1984-1991, ce qui indique une amélioration de l'état des stocks depuis la mise en œuvre du moratoire sur la pêche commerciale du saumon. La proportion de gros saumons dans les trois cours d'eau était plus forte que la moyenne pour 1984-1991. Il est fort peu probable que les besoins au titre de la conservation dans ces trois cours d'eau n'aient pas été satisfaits en 1999. En se fondant sur la production de saumoneaux de Western Arm Brook en 1999, on s'attend à ce que les remontes de saumons unibermarins en 2000 soient plus faibles qu'en 1999 et que la moyenne pour 1992-1998, pourvu que le taux de survie en mer ne change pas. Le taux de survie en mer des saumoneaux revenus à Western Arm Brook à l'état de saumons unibermarins se chiffrait à 6,1 % en 1999, soit plus de deux fois le pourcentage observé en 1997. On s'attend à ce que les échappées de géniteurs dans les trois cours d'eau soient supérieures aux besoins au titre de la conservation en 2000, pourvu que le taux de survie en mer soit semblable à celui de 1999. Une baisse du taux de survie en mer semblable à celle qui s'est manifestée en 1997 signifierait que les besoins au titre de la conservation dans Western Arm Brook ne seraient probablement pas comblés en 2000. Il sera peut-être possible de capturer plus de saumons dans les eaux en aval des barrières de dénombrement installées dans ces trois cours d'eau grâce à l'amélioration générale de l'état des stocks et au contrôle accru que permet le système de classification des cours d'eau. Mais à cause de l'incertitude que soulève le taux annuel de survie en mer des saumons de Western Arm Brook, la pêche dans ce cours d'eau est déconseillée tant que le besoin au titre de la conservation (300 saumons) n'aura pas été comblé. En outre, l'expansion des pêches en amont des barrières de dénombrement installées dans ces trois cours d'eau n'est pas recommandée à moins que le niveau des prises récréatives puisse être établi avec précision.

INTRODUCTION

Lomond River, Torrent River, and Western Arm Brook are three of fourteen scheduled rivers in Salmon Fishing Area (SFA) 14A (Fig. 1). Atlantic salmon adult returns are monitored on all three rivers and smolt production is monitored on Western Arm Brook. Adult returns have been monitored at fishways on Lomond River and Torrent River since the 1960s and at a counting fence on Western Arm Brook since 1971. Smolt production has been monitored at the counting fence on Western Arm Brook since 1971. The fishways on Lomond River and Torrent River are located approximately 5.0 km and 2.0 km, respectively, upstream from the mouth of the river. The counting fence on Western Arm Brook is located just above the head of tide.

The recreational salmon fishery on Lomond River is downstream from the fishway (since 1978) and was controlled by an individual river quota from 1986-1998. The quota was increased to 375 small salmon retained in 1995 from 350 in place since 1986. The recreational salmon fishery on Torrent River is also downstream from the fishway and prior to 1999 was restricted to catch and release angling only until a minimum spawning escapement had passed upstream through the fishway. Retention angling was then permitted. The minimum escapement was first set at 1,000 salmon in the 1970s and was reduced to 750 salmon in 1995. Catch and release angling prior to the minimum escapement being achieved was first permitted in 1996. The recreational salmon fishery on Western Arm Brook has been closed since 1989.

The commercial salmon fishery in insular Newfoundland including SFA 14A has been under a moratorium since 1992. This was a major management initiative to increase the number of adult salmon returns to rivers. In addition, stricter controls were implemented in the recreational fishery to increase spawning escapements. The commercial cod fishery moratorium implemented in this area in August 1993 was also expected to contribute to an increase in adult returns. However, there was still a potential, in 1992, for high fishing mortality on salmon at sea due to the presence of cod traps.

The effect that the commercial salmon fishery moratorium and other management changes had on adult salmon returns in 1992-99 can be examined on Lomond River, Torrent River and Western Arm Brook based on counts of adult salmon at counting facilities compared to previous years (1984-91). Recreational salmon fishery catches are known for these rivers. Therefore, changes in spawning escapements can also be evaluated relative to previous years. Habitat information and salmon biological characteristics are also known. Therefore, changes in spawning escapements can be evaluated relative to established conservation requirements. The effect of the moratorium on recruitment can also be evaluated by adjusting returns of small salmon to account for commercial exploitation. Annual variability in marine survival of smolts can be also evaluated at Western Arm Brook relative to pre-moratorium

years based on the percentage returning as adult one-sea-winter (1SW) salmon the following year. In addition, possible causes of variable marine survival can be examined. Following the unexpected decrease in marine survival of salmon smolts in 1997, several possible sources of mortality were identified (Dempson et al., 1998) including changes in run timing, water temperature and predation by birds (CSAS, 1998).

METHODS

RECREATIONAL FISHERY

Recreational salmon fishery data on Lomond River and Torrent River were estimated based on the licence stub return system in 1997-99 (O'Connell, et al. MS 1998). Previously, recreational salmon fishery data were compiled from weekly reports of small (<63 cm) and large (>= 63 cm) salmon catches completed by the Department of Fisheries and Oceans (DFO) river guardians (Mullins et al., MS 1989; Mullins and Jones, MS 1993a; and Mullins and Jones, MS 1993b). These may not be directly comparable to data from the licence stub return system. Recreational salmon fishery data for the three rivers are given in Appendices 1-3.

ADULT RETURNS AND SPAWNING ESCAPEMENTS

a) Adult Counts and Run Timing

Counting facilities on all three rivers were monitored on a daily basis the same as in previous years. The only exception was that the fishway on Lomond River was not monitored in 1989-91, but fish were observed passing upstream through the fishway. The counts of small and large salmon in those years were estimated based on the mean of the previous three years when fisheries management plans were similar.

Run timing of small salmon was measured as the date that the 25th, 50th and 75th percentiles of cumulative counts occurred at each counting facility.

Water temperature (C) at the counting fence and in the estuary of Western Arm Brook was recorded hourly using a 'Hobo-temp' temperature logger and a 'Ryan' thermograph'.

Water levels at Western Arm Brook in 1999 were recorded at the adult counting trap.

b) Adult Returns

The total returns to the river (TRR) of adult small and large salmon were based on counts at counting facilities and removals in the recreational fishery below the counting facility according to the equation:

$$\mathbf{TRR = CNT + RET + HRM}$$

Where:

CNT = count of salmon at counting facility
RET = number of salmon retained
HRM = hook-and-release mortality

$$\mathbf{HRM = REL \times 0.1}$$

Where:

REL = hook and release mortality

Removals in the recreational salmon fishery include retained fish plus an assumed mortality rate of 0.1 on released small and large salmon. This mortality rate was based on consultations with anglers. It was assumed that catch and release mortality occurred only below the counting facilities where angling was permitted. No adjustments were made for any other unrecorded mortality above or below the counting facilities.

Total returns of small and large salmon were calculated separately.

Returns of small and large salmon were compared with those in 1998 and the 1992-98 and 1992-96 means. The 1992-96 mean reflects years with a consistent management approach in the first five years following the commercial salmon fishery moratorium. Due to the high proportion of river age 3 and 4 salmon, a high proportion of the returns in 1997 and 1998 were expected to be the progeny of spawners in 1992. This would have been the first year-class with a contribution from spawners released as a result of the closure of the commercial salmon fishery. Returns in 1992-96 would have been comprised of year-classes prior to the closure and would have included salmon normally caught in the commercial fishery.

c) Spawning Escapements

Spawning escapements of small and large salmon to each river were calculated separately by subtracting retained catches, mortalities due to catch and release and other known removals from the total returns:

SE = TRR – RET – HRM

Where:

TRR = total return of small or large salmon
RET = number of salmon retained
HRM = hook-and-release mortality (10% of hooked and released fish)

CONSERVATION REQUIREMENTS AND POTENTIAL EGG DEPOSITIONS

a) Conservation Requirements

Conservation requirements, were calculated in terms of eggs, based on 2.4 eggs/m^2 (Elson, 1975) for fluvial habitat (Elson, 1957) on all three rivers, and 368 eggs/ha for lacustrine habitat on Lomond River and 105 eggs/ha for Torrent River and Western Arm Brook (O'Connell et al., MS 1991). The egg deposition rate for fluvial habitat includes an adjustment for poaching and disease; whereas, the rate for lacustrine habitat does not include an adjustment. The conservation requirement (CR) for each river was calculated according to the formulae:

1. Lomond River

CR = (fluvial area x 2.4) + (lacustrine area x 105)

2. Torrent River and Western Arm Brook

CR = (fluvial area x 2.4) + (lacustrine area x 368)

The habitat measurements available for Lomond River, Torrent River and Western Arm Brook are as follows:

River	Fluvial Area (m2)	Lacustrine Area (ha)
Lomond River	215,600	1,570
Torrent River	516,800	2,323
Western Arm Brook	290,000	2,017

It is important to note that for Lomond River, the amount of available fluvial habitat was measured from detailed stream surveys. For Torrent River and Western Arm Brook, available fluvial habitat was based on aerial surveys (Traverse, 1971). Available lacustrine habitat on the three rivers was measured from 1:50,000 scale topographic maps using the appropriate dot grid scale.

Conservation requirements in terms of eggs were expressed in terms of a spawning requirement of adult salmon based on mean weights and proportion of females for 1992-96. The means of these years were used to account for potential change in mean weight as a result of elimination of selective commercial fishing mortality since 1992. The minimum proportion of large

salmon and the maximum proportion of small salmon observed in 1992-96 were used to apportion the spawning requirements into numbers of small and large salmon.

Conservation requirements in terms of eggs as well as the number of spawning adult salmon that would normally be required to achieve this level of egg deposition are as follows (Mullins, MS 1997):

	Conservation Requirements			
		Spawners		
River	Eggs	Small	Large	Total
Lomond River	1,095,200	557	23	580
Torrent River	1,484,235	562	30	592
Western Arm Brook	907,785	284	3	287

b) Potential Egg Deposition

Potential egg deposition (ED) by small and large salmon on each river was estimated by the following formulae based on available biological information:

$$ED = SE \times PF \times F$$

Where:

SE = spawning escapement
PF = proportion female
F = fecundity

$$F = RF \times MW$$

Where:

RF = relative fecundity (# eggs/kg)
MW = mean weight of females

The relative fecundity of 1,783 eggs/kg of body weight for small and large salmon was estimated from an average of 3,388 (N=264) eggs per female for Western Arm Brook in 1979-80 (Chadwick et al., 1986) based on a mean weight of 1.90 kg.

Mean weight and proportion female were obtained from sampling conducted at the counting facilities and in the recreational salmon fishery. Sex composition was usually determined by external examination at counting facilities and by internal examination in the recreational salmon fishery samples. For small salmon, only information from internally sexed fish was used to estimate egg deposition, whereas for large salmon, information from both internally and externally sexed fish was used. Because samples sizes are small (<30) in some years, pooling of data is sometimes necessary in order to obtain an adequate sample size. This was particularly important for years since 1992 when there

was a potential for increased body size due the closure of the commercial salmon fishery.

Pooled biological information for 1999 was as follows:
Lomond (small) - mean weight and percent female based on 1992-99 mean.
Lomond (large) - mean weight females based on 1978-99 mean; percent female based on 1993.
Torrent (small) - mean weight and percent female based on 1992-99 mean.
Torrent (large) - mean weight and percent female based on 1980-97 mean.
Western Arm (small) - mean weight and percent female based on 1992-99 mean.
Western Arm (large) - mean weight and percent female based on 1992-99 mean.

	Small salmon			Large salmon		
River	Mean Wt. Females (kg)*	Fecundity	Prop. Female*	Mean Wt. Female (kg)*	Fecundity	Prop. Female*
Lomond River	1.59 (41)	2,835	0.587 (109)	3.62 (21)	6,454	0.857 (7)
Torrent River	1.78 (30)	3,174	0.649 (74)	4.04 (27)	7,203	0.638 (213)
Western Arm Brook	2.09 (104)	3,726	0.827 (133)	4.50 (59)	8,023	0.763 (80)

* Numbers in parentheses refer to pooled samples sizes.

The percentage of the conservation egg deposition requirement (CR) achieved was calculated according to the formula:

% Achieved = ED (small + large) / CR

There is some uncertainty in the egg deposition estimate because of the possibility of error in the estimates of biological parameters used in the calculations. This was expressed in the form of a probability density function using simulation techniques. The technique involved recalculating the egg deposition estimates 5000 times while allowing the values used in the calculation to vary with each calculation or simulation. The following parameter values were allowed to vary within a uniform distribution with each simulation step: 1) fecundity of small and large salmon and 2) the proportion of female small and large salmon. Both were allowed to vary by a 20% coefficient of variation. The frequency and probability distributions of the resulting egg deposition estimates were plotted to determine the mode and the 2.5^{th} and 97.5^{th} percentiles.

SMOLT COUNTS, MARINE SURVIVAL AND ANTICIPATED 1SW RETURNS

Annual smolt production has been recorded at the counting fence on Western Arm Brook since 1971.

Marine survival of smolts was taken as the percentage of the smolt production in year *i* that returned to the river as virgin one-sea-winter (1SW) adult salmon in year *i*+1. The number of 1SW returns was calculated from total returns of small salmon based on the proportion of 1SW salmon sampled at the counting fence. One in ten returning small salmon at the counting fence was sampled.

In the absence of marine exploitation following the commercial salmon fishery moratorium in 1992, returns of small salmon were assumed to represent the total recruitment. Therefore, the marine survival calculation in these years was not directly comparable to previous years. O'Connell, et al. (MS 1997) described a technique whereby it was possible to retrospectively construct, in selected rivers with counting facilities, total recruitment of small salmon (or total number of small salmon recruits) prior to any exploitation. Small salmon recruits for Western Arm Brook prior to 1992 were derived based on total returns to the river and an assumed commercial exploitation rate of 0.60.

RESULTS

RECREATIONAL SALMON FISHERY

The recreational salmon fisheries on Lomond River and Torrent River opened 15 June and closed 7 September 1999. There were no in-season closures due to low water levels. The fishery on Western Arm Brook remained closed in 1999. Both the Lomond River and Torrent River were designated as Class II rivers under the new recreational salmon fishery management plan introduced in 1999. The retention limit on rivers in Class II was four small salmon for the season. This was the same as the total retention limit in 1998 but without the split season restrictions that were in place in 1998 and since 1994. With the split season, only one fish could be retained before 5 July and three after and anglers were required to release their catch before 5 July in order to continue fishing. The daily catch and release limit was increased to four in 1999, up from two in 1998. Catch and effort statistics for 1974-99 are given in Appendices 1-3. Effort values were not available from license stub returns for 1997-99.

a) Lomond River

The quota of 375 small salmon was dropped in 1999 as it appeared to be no longer effective or necessary in controlling the catch on the river (Mullins et al., MS 1999). The retained catch of 253 small salmon in 1999 was 26% higher than in 1998 but the released catch was 59% less in spite of the increase in the daily catch and release limit indicating less effort was directed towards catch and release angling. This was likely due to the removal of the split season restriction in effect in 1998 requiring anglers to release their catch before 5 July in order to continue fishing. The total retained plus released catch of small salmon in 1999

was 20% less than in 1998 and 55% less than in 1997 and the 1992-96 mean. The released catch of large salmon in 1999 was more than three times the catch in 1998 and the highest recorded for the river.

In the first five years (1992-96) of the commercial salmon fishery moratorium, retained plus released catches of small and released catches of large salmon on Lomond River increased relative to pre-moratorium years (1984-91). Based on license stub return data, this continued in 1997-99. However, it is noted that data for 1999 are preliminary.

b) Torrent River

The minimum spawning escapement of 750 salmon above the fishway before the start of the retention fishery was dropped in 1999 as this number of fish usually passed through the fishway within a few days (12 days in 1998) of the start of the run. The retained catch of 293 small salmon was about 7% higher than in 1998 but the released catch was 47% lower in spite of an increase in the daily catch and release limit. As on Lomond River, the removal of the split season for retention of small salmon appears to have resulted in less effort directed towards catch and release angling in 1999. The fact that the retained catch remained similar to 1998 may be due to the fact that the total retention limit of four salmon did not change. Torrent is generally a late run river so the restriction of one fish retained before 5 July in 1998 would have had little effect on the total catch compared to 1999. In addition, the fishery was normally not opened for retention until the minimum spawning escapement was reached. This usually occurred in early July. The total retained plus released catch of small salmon was 29% less than in 1998. The released catch of large salmon was 35% higher than in 1998 and the highest recorded on the river. This may be related to the removal of the minimum spawning escapement restriction allowing an earlier start to the fishery.

During the first five years (1992-96) of the commercial salmon fishery moratorium, with the exception of 1994, retained plus released catches of small and large salmon on Torrent River were the highest since 1965. It appears that except for some slight fluctuation, this continued in 1997-99. Catch per unit of effort (CPUE) also increased in the first two years of the moratorium but then decreased in 1994-96. This was due to an increase in angling effort in 1994-96 to nearly four times the effort in pre-moratorium years. However, it is noted that data for 1999 are preliminary.

ADULT RETURNS

Dates of operation of counting facilities are given in Table 1.

Run timing of small and large salmon was among the earliest recorded at Torrent River fishway in 1999 while it was among the latest at Western Arm Brook counting fence (Figs. 2-4). Run timing at the Lomond River fishway was about average and the latest of the three rivers. This may be due to the fact that the Lomond River facility is the farthest from the mouth of the river, although it is farther south.

Water levels were low on many rivers in 1999 and may have delayed run timing on some rivers. Water levels were extremely low on Western Arm Brook in July (Fig. 5). Salmon were observed holding up in the estuary until water levels increased in mid-August allowing fish to move upstream (Fig. 5). It is not expected that the total count would have been affected by water levels.

Total counts of small and large salmon at the three counting facilities are given in Table 2. Counts at the counting fence on Western Arm Brook represent the total returns to the river.

Total returns of salmon to the three rivers are given in Table 3 and in Fig. 6. Returns of small salmon to Lomond River were 42% higher than in 1998 and 8% higher than the 1992-98 mean. Returns of large salmon were the third highest on record and 46% higher than the 1992-98 mean. Returns of small salmon to Torrent River were 19% less than in 1998 and 10% lower than the 1992-98 mean. Returns of large salmon in 1999 were 46% less than in 1998 and 13% less than the 1992-98 mean. Returns of small salmon to Western Arm Brook were 39% less than in 1998 but 10% higher than the 1992-98 mean. Returns of large salmon were 82% less than in 1998 and 50% less than the 1992-98 mean. Returns of both small and large salmon to all three rivers were higher than the 1984-91 means indicating improvements in the stocks as a result of the commercial salmon fishery moratorium.

The proportion of large salmon in 1999 based on counts at the three counting facilities were lower than in 1998 but among the highest since 1992 and higher than the 1984-91 means (Table 4).

SPAWNING ESCAPEMENTS AND POTENTIAL EGG DEPOSITIONS

Spawning escapements of small and large salmon are given in Table 5. Spawning escapements on all three rivers since 1992 have been above the 1984-91 mean.

Potential egg depositions and the percentage of conservation requirements achieved in 1984-99 are given in Table 6. Conservation requirements above the counting facilities were exceeded on all three rivers in 1999 - 181%, 680% and 370%, on Lomond River, Torrent River and Western Arm Brook, respectively. The percentage achieved increased on Lomond River but decreased on Torrent River and Western Arm Brook in comparison to 1998.

It is recognised that the potential egg depositions estimated for Lomond River, Torrent River and Western Arm Brook are based on point estimates of the number of eggs deposited per small and large salmon spawner. These values are affected by uncertainty in values used to derive them such as the mean weight of females, the percentage female and the relative fecundity. Recalculation of egg depositions by allowing the estimates of eggs per spawner to vary by a coefficient of variation of 20%, indicates that there is a very low probability that the conservation requirements on all three rivers were not achieved in 1999 (Fig. 7).

SMOLT COUNTS, MARINE SURVIVAL AND ANTICIPATED 1SW RETURNS IN 1999

The smolt production of 13,500 recorded at Western Arm Brook in 1999 was 21% less than in 1998, 13% less than the 1992-98 mean and 10% less than the 1984-91 mean (Table 7; Fig. 8).

The highest number of smolts counted since 1992 was in 1997. On the basis of an average smolt age of four years, the majority of these were produced from salmon that spawned in 1992. This was the first spawning year-class since the closure of the commercial salmon fishery in 1992. However, the spawning escapements and egg depositions in 1992 were among the lowest recorded on the river (Table 6). This may have been due to the fact that in 1992 there was still a potential for high by-catch of salmon in cod fishing gear. The commercial cod fishery moratorium was implemented in 1993. Salmon spawning escapements and egg depositions increased in 1993 and 1994 but did not result in increased smolt production in 1998 and 1999. Smolt counts in 1998 and 1999 were both lower than in 1997. Thus far, higher spawning escapements and higher potential egg depositions on the river since 1992 have not resulted in higher smolt production. This has also occurred in the past. Similar levels of egg deposition in 1973 and 1983 also produced lower survival to the smolt stage (Fig. 9). In general, egg to smolt survival at Western Arm Brook has tended to be lower at higher egg depositions suggesting some density dependent mortality in freshwater. Total egg deposition in 1995 was similar to 1993 and 1994 (Table 6). Assuming similar egg to smolt survival and smolt age distribution, smolt production in 2000 is expected to be similar to 1999.

The marine survival of smolts that returned to the river as 1SW salmon in 1999 was 6.1% (Table 7). This was 8% lower than the previous year and 5% lower than the 1992-98 mean but was 52% higher than the 1984-91 mean (Table 7).

With the exception of 1997, marine survival of smolts at Western Arm Brook has increased since 1992 compared to the 1984-91 mean (Table 7; Fig. 10). This change can be attributed to in the absence of commercial salmon exploitation since 1992. However, adjusting the marine survival in 1972-91 for commercial exploitation, suggests that marine survival has tended to decline over the long term (Fig, 10). Marine survival in 1992-99, while increasing somewhat as a result of the closure of the commercial salmon fishery, has remained relatively low in comparison to the long term (Fig. 10). This highlights the fact that factors other than commercial exploitation play an important role in the survival of salmon in the marine environment and that these factors are not static and that some may have increased in their influence in recent years.

Marine survival experienced at Western Arm Brook in 1997 was among the lowest recorded even compared to years when a commercial salmon fishery was in place (Fig. 10).

The run timing of smolts at Western Arm Brook in 1999 was the second earliest recorded and the earliest since 1992 (Fig. 11). The earliest run timing was in 1979. The mean June water temperatures recorded at the counting fence and in the estuary were among the warmest in recent years (Figs. 12-13). These conditions represent a change compared to recent years but their effect on smolt survival is unknown at this point.

It was expected that the 28% lower smolt count on Western Arm Brook in 1998 compared to 1997 would result in lower returns of small 1SW salmon in 1999 (Mullins et al., MS 1999). As expected, returns in 1999 were lower than in 1998 (Table 6) but were even lower than expected because of the 8% lower marine survival (Table 7).

Assuming that marine survival in 2000 will be the same as for 1999 (6.1%), it is expected that 823 1SW salmon will return to Western Arm Brook next year. This would be 21% less than in 1999.

The difference between expected and actual 1SW returns based on this method have been highly variable because of the instability in marine survival. However, the differences were positive in five out of eight years indicating higher than expected survival.

Year	Expected	Observed	% Difference.
1992	297	479	+61
1993	550	817	+49
1994	826	919	+11
1995	659	823	+25
1996	1342	1230	-8
1997	1218	429	-65
1998	715	1581	+121
1999	1131	1044	-8
2000	823		

The maximum negative difference in expected returns was 65% in 1997. If this were the case in 2000, assuming no recreational harvests, spawning escapements would not produce sufficient egg deposition on Western Arm Brook to achieve the conservation requirement. If recreational harvests are to be permitted on Western Arm Brook, it should only be after sufficient spawning escapements have entered the river to achieve the conservation requirement.

DISCUSSION

Salmon stocks on Lomond River, Torrent River and Western Arm Brook exceeded conservation requirements in 1999, as in every year since 1992. This was due to increased spawning escapements of small and large salmon and increased proportion of large salmon compared to the 1984-91 means. These increases can be attributed to the closure of the commercial salmon fishery in 1992 and to the reduction of salmon by-catch with the closure of the commercial cod fishery since 1993, especially for Lomond River and Western Arm Brook. The salmon stock on Torrent River would also have benefited from these closures but improvements since the 1970s can also be attributed to the successful colonisation of a major portion of the watershed with adult salmon and possibly with an early high survival of juvenile salmon in the freshwater environment. The potential for continued future growth in all three of these stocks is evidenced by improvements in juvenile densities recorded at Western Arm Brook (Mullins et al., MS 1999) and by the continued higher spawning escapements, especially of large salmon, afforded by the closure of commercial salmon and cod fisheries. However, considering the unexpectedly low marine survival recorded at Western Arm Brook in 1997 even when compared to years when commercial fisheries were in place, future improvements are by no means assured. In fact, when marine survival prior to 1992 is adjusted for commercial exploitation, it is clear that there has been a continued decline in marine survival in recent years. This decline is not unique to Western Arm Brook and the factors contributing to such a decline are currently unknown (CSAS, 1998). However, the fact highlights the need for further investigation and for caution in the management of fisheries harvests. In spite of recent improvements in the status of these stocks there is still a need to manage fisheries in such a way that the most productive spawning levels are maintained.

There is also reason to be cautious in the interpretation of stock assessment results. In particular, the annual variability in the effect of atresia on fecundity (O'Connell et al., MS 1997) and the potential for spawner mortality upstream of counting facilities as well as other egg losses in the river result in estimates of egg deposition that should be treated as potential only. The fecundity values used to calculate egg depositions for all three rivers were based on biological characteristics of Western Arm Brook salmon in 1979-80 (Chadwick et al., 1986). Fecundity estimates should be revised for each river, given the potential for change in the body size of returning adults as a result of the moratorium. Cautions associated with estimates of parameter values used to calculate conservation requirements are discussed in detail by O'Connell and Dempson (1995). Some of the uncertainty created by these estimates has been incorporated into the calculation of egg deposition to simulate variability.

The habitat measurements on which conservation requirements are based were taken from aerial surveys conducted in the early 1970s (Traverse, 1971). These measurements should be verified and updated based on currently available digitised maps. Until this work is completed, habitat estimates should be viewed as minimum values.

Both Lomond River and Torrent River currently support recreational salmon fisheries while continuing to exceed conservation requirements. Currently fisheries are not permitted upstream of the fishways on these two rivers. It is recommended that this restriction remain in place until habitat estimates can be reviewed. An upward revision of these estimates could result in an increase in the conservation requirements for these rivers.

In addition, because of the long time series of salmon data available from counting facilities on Lomond River, Torrent River and Western Arm Brook, there exists a rare opportunity to monitor changes in the stocks relative to pre-moratorium years. This can be done by studying the relationship between the number of spawners and recruits and between egg deposition and smolt production. This can only be accomplished if counting facilities remain in place to monitor returns to the rivers and if there is an accurate accounting of removals in order to determine spawning escapements. Currently spawning escapements on these three rivers are known because angling is not permitted above counting facilities. It is recommended that fisheries not be supported above these facilities unless the angling catch can be accurately determined.

Given the improvements observed in the salmon stocks on these three rivers and the added control afforded by the introduction of the river classification system in 1999, there may be opportunities for increased harvests below, rather than above, counting facilities. However, given the variability in marine survival observed for Western Arm Brook it is cautioned that harvests on this river in

particular, should not be permitted until the conservation requirement has been achieved.

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Table 1. Dates of operation of counting facilities at Lomond River, Torrent River and Western Arm Brook, 1971-1999.

Year	Lomond River	Torrent River	Western Arm Brook
1971	26 June to 25 September	5 June to 23 October	14 May to 28 September
1972	8 July to 16 September	11 June to 11 November	27 May to 22 September
1973	16 July to 8 September	23 June to 4 November	25 May to 17 September
1974	6 July to 7 September	8 June to 16 November	1 June to 24 August
1975	7 June to 16 August	29 June to 11 October	23 May to 6 October
1976	12 June to 28 August	3 July to 23 October	19 May to 25 September
1977	2 July to 10 September	2 July to 1 October	16 May to 23 October
1978	1 July to 29 September	4 June to 11 November	25 May to 31 December
1979	23 June to 8 September	30 June to 3 November	25 May to 23 September
1980	28 June to 13 September	28 June to 11 October	26 May to 12 October
1981	20 June to 5 September	20 June to 5 September	14 May to 9 September
1982	26 June to 11 September	28 June to 2 October	1 June to 27 September
1983	1 July to 28 August*	23 June to 21 October	11 May to 27 October
1984	21 June to 1 November	25 June to 29 October	24 May to 26 October
1985	11 June to 29 October	12 June to 31 October	5 June to 30 October
1986	6 June to 4 October	24 June to 1 October	14 May to 25 October
1987	**	3 June to 9 October	13 May to 27 October
1988	**	22 June to 5 October	19 May to 31 October
1989	**	26 June to 20 September	19 May to 17 October
1990	**	4 July to 19 October	25 May to 24 October
1991	**	26 June to 22 October	29 May to 28 October
1992	15 June to 25 September	1 July to 23 September	28 May to 19 October
1993	29 June to 25 September	28 June to 12 October	31 May to 19 October
1994	24 June to 28 October	18 July to 24 October	27 May to 24 October
1995	12 July to 23 September	16 July to 1 November	26 May to 29 September
1996	19 June to 18 November	19 June to 31 October	3 May to 27 September
1997	28 June to 20 October	17 June to 7 November	13 May to 2 October
1998	23 June to 10 October	17 June to 9 October	6 May to 24 September
1999	15 June to 29 September	16 June to 14 October	13 May to 30 September

* Fishway operational but fish not counted after 28 August.

** Fishway operational but dates not available.

Table 2. Counts of small and large Atlantic salmon at counting facilities on Lomond River, Torrent River and Western Arm Brook, 1974-1999. Numbers in bold type are partial counts.

Year	Lomond River		Torrent River		Western Arm Brook		
					Small		
	Small	Large	Small	Large	Unadjusted	Adjusted*	Large
1971	6	0	54	4	427	.	305
1972	30	15	64	3	309	.	9
1973	108	110	96	12	554	.	30
1974	41	33	38	3	382	.	4
1975	**1**	**0**	191	25	631	.	1
1976	132	11	341	47	520	.	0
1977	192	11	789	33	362	.	3
1978	117	12	971	21	293	.	1
1979	195	1	1984	39	1578	.	0
1980	301	19	792	63	435	.	3
1981	110	50	2101	97	451	.	1
1982	275	16	2112	523	394	.	3
1983	220	7	2007	442	1141	.	4
1984	440	47	1805	288	120	.	0
1985	190	14	1553	30	**165**	416	1
1986	354	32	2815	92	**252**	525	0
1987	355	11	2505	68	378	.	1
1988	437	21	2075	44	**102**	251	1
1989	**382**	**21**	1369	60	**414**	455	0
1990	**391**	**18**	2296	82	**124**	444	0
1991	**403**	**20**	1441	71	233	.	1
1992	435	80	2347	169	480	.	8
1993	526	34	4009	222	947	.	8
1994	701	50	3592	331	954	.	31
1995	1003	95	5800	611	823	.	33
1996	601	93	6923	507	1230	.	50
1997	783	72	3659	666	509	.	55
1998	542	126	4999	757	1718	.	128
1999	829	113	4008	399	1046	.	22
Mean (92-98)	656	79	4476	466	952	.	45
95% CL=+/-	177	28	1424	211	396	.	38
CV	29.2	38.8	34.4	49.0	45.0	.	91.7
N	7	7	7	7	7	.	7
Mean (84-91)	369	23	1982	92	224	.	1
95% CL=+/-	66	10	442	38	100	.	0
CV	21.5	49.9	26.7	88.9	53.4	.	106.9
N	8	8	8	8	8	.	8

*Note: Counts in the following years were adjusted to account for fish that moved upstream after the counting fence was removed:

1. 1985-86 small salmon count adjusted based on the ratio of marked to unmarked small at the counting fence (Claytor and Mullins, 198
2. 1988 small salmon count adjusted based on kelt counts in 1989.
3. 1989 small salmon count adjusted based on the proportion of marked kelts (131/144) recaptured in 1990.
4. 1990 small salmon count adjusted based on the proportion of marked kelts (43/154) recaptured in 1991.

Table 3. Total returns of small and large Atlantic salmon to Lomond River, Torrent River and Western Arm Brook, 1971-1999.

Year	Lomond River		Torrent River		Western Arm Brook	
	Small	Large	Small	Large	Small	Large
1971*	60	1	107	9	632	305
1972	283	50	86	6	406	9
1973	394	165	184	15	797	30
1974	365	52	96	7	506	4
1975	259	20	314	31	639	1
1976	782	38	341	47	552	0
1977	687	45	789	33	373	3
1978	462	41	1002	25	315	2
1979	430	3	2049	42	1578	0
1980	594	32	792	63	465	5
1981	617	53	2268	115	492	1
1982	583	23	2299	525	467	3
1983	471	10	2089	443	1141	4
1984	986	75	1805	288	235	0
1985	393	14	1623	30	467	1
1986	725	37	3155	93	527	0
1987	652	12	2670	68	437	1
1988	841	24	2388	44	422	1
1989	652	22	1512	60	455	0
1990	777	19	2518	82	444	0
1991	731	21	1591	71	233	1
1992	794	86	2832	170	480	8
1993	816	38	4215	224	947	8
1994	1038	56	3827	332	954	31
1995	1365	101	6168	615	823	33
1996	982	98	7371	509	1230	50
1997	1300	77	4033	674	509	55
1998	766	128	5329	766	1718	128
1999	1091	121	4330	411	1048	22
Mean (92-98)	1009	83	4825	470	952	45
95% CL=+/-	225	28	1438	214	396	38
CV	24.1	36.0	32.2	49.3	45.0	91.7
N	7	7	7	7	7	7
Mean (84-91)	720	28	2158	92	403	1
95% CL=+/-	143	17	508	68	91	0
CV	23.8	72.7	28.2	88.8	27.0	107.5
N	8	8	8	8	8	8

* Incorrect sizing suspected at Western Arm Brook (Moores and Ash, 1984).

Table 4. Annual variation in proportion of small and large Atlantic salmon observed at counting facilities on Lomond River, Torrent River and Western Arm Brook, 1971-1999.

Year	Lomond River		Torrent River		Western Arm Brook	
	Small	Large	Small	Large	Small	Large
1971	1.00	0.00	0.93	0.07	0.58	0.42
1972	0.67	0.33	0.96	0.04	0.97	0.03
1973	0.50	0.50	0.89	0.11	0.95	0.05
1974	0.55	0.45	0.93	0.07	0.99	0.01
1975	1.00	0.00	0.88	0.12	1.00	0.00
1976	0.92	0.08	0.88	0.12	1.00	0.00
1977	0.95	0.05	0.96	0.04	0.99	0.01
1978	0.91	0.09	0.98	0.02	1.00	0.00
1979	0.99	0.01	0.98	0.02	1.00	0.00
1980	0.94	0.06	0.93	0.07	0.99	0.01
1981	0.69	0.31	0.96	0.04	1.00	0.00
1982	0.95	0.05	0.80	0.20	0.99	0.01
1983	0.97	0.03	0.82	0.18	1.00	0.00
1984	0.90	0.10	0.86	0.14	1.00	0.00
1985	0.93	0.07	0.98	0.02	1.00	0.00
1986	0.92	0.08	0.97	0.03	1.00	0.00
1987	0.97	0.03	0.97	0.03	1.00	0.00
1988	0.95	0.05	0.98	0.02	1.00	0.00
1989	0.95	0.05	0.96	0.04	1.00	0.00
1990	0.96	0.04	0.97	0.03	1.00	0.00
1991	0.95	0.05	0.95	0.05	1.00	0.00
1992	0.84	0.16	0.93	0.07	0.98	0.02
1993	0.94	0.06	0.95	0.05	0.99	0.01
1994	0.93	0.07	0.92	0.08	0.97	0.03
1995	0.91	0.09	0.90	0.10	0.96	0.04
1996	0.87	0.13	0.93	0.07	0.96	0.04
1997	0.92	0.08	0.85	0.15	0.90	0.10
1998	0.81	0.19	0.87	0.13	0.93	0.07
1999	0.88	0.12	0.91	0.09	0.98	0.02
Mean (92-98)	0.89	0.11	0.91	0.09	0.96	0.04
95% CL=+/-	0.05	0.05	0.03	0.03	0.03	0.03
CV	5.5	44.1	4.1	39.6	3.2	72.0
N	7	7	7	7	7	7
Mean (84-91)	0.94	0.06	0.96	0.04	1.00	0.00
95% CL=+/-	0.02	0.02	0.03	0.03	0.00	0.00
CV	2.4	38.2	4.1	86.3	0.2	113.1
N	8	8	8	8	8	8

Table 5. Spawning Escapements of small and large Atlantic salmon on Lomond River,Torrent River and Western Arm Brook, 1971-1999. Spawners on Torrent in 1972-76 include surviving spawners transferred from Western Arm Brook (60, 206, 83, 223, 100).

Year	Lomond River		Torrent River		Western Arm Brook	
	Small	Large	Small	Large	Small	Large
1971	6	0	54	4	427	305
1972	30	15	120	3	249	9
1973	108	110	299	12	348	30
1974	41	33	121	3	290	4
1975	1	0	404	25	285	1
1976	132	11	441	47	365	0
1977	192	11	789	32	352	3
1978	117	12	971	21	289	1
1979	195	1	1,984	39	1,578	0
1980	301	19	789	83	427	3
1981	110	50	2,101	97	447	1
1982	275	16	2,112	523	391	3
1983	220	7	2,007	442	1,140	4
1984	440	47	1,805	288	117	0
1985	189	14	1,551	30	416	1
1986	353	32	2,815	92	525	0
1987	355	11	2,482	68	378	1
1988	437	21	2,075	44	251	1
1989	382	21	1,367	60	455	0
1990	391	18	2,296	82	444	0
1991	403	20	1,440	71	233	1
1992	419	80	2,344	169	480	8
1993	504	33	4,009	222	947	8
1994	695	49	3,592	331	954	31
1995	983	95	5,800	611	796	30
1996	601	93	6,923	507	1,189	48
1997	783	72	3,659	666	508	55
1998	541	125	4,999	757	1,650	128
1999	819	110	4,008	399	1,045	22
Mean (92-98)	647	78	4475	466	932	44
95% CL=+/-	177	28	1424	211	375	38
CV	29.6	39.2	34.4	49.0	43.5	93.5
N	7	7	7	7	7	7
Mean (84-91)	369	23	1979	92	352	1
95% CL=+/-	67	10	440	68	115	0
CV	21.6	49.9	26.6	88.9	39.2	106.9
N	8	8	8	8	8	8

Table 6. Total returns, spawning escapement, potential egg deposition and percentage of egg deposition requirement achieved by small and large Atlantic salmon on Lomond River, Torrent River, and Western Arm Brook, 1984-1999. Numbers in bold type were estimated based on partial counts.

Year	Total Returns		Spawning Escapement		No. Eggs x 10^6			% Eggs Achieved
	Small	Large	Small	Large	Small	Large	Total	
Lomond River								
1984	986	75	440	47	0.7356	0.0758	0.8114	74
1985	393	14	189	14	0.3160	0.0226	0.3385	31
1986	725	37	353	32	0.5901	0.0516	0.6417	59
1987	852	12	355	11	0.5935	0.0177	0.6112	56
1988	841	24	437	21	0.7306	0.0339	0.7644	70
1989	**852**	**22**	382	21	0.6386	0.0339	0.6725	61
1990	**777**	**19**	391	18	0.6537	0.0290	0.6827	62
1991	**731**	**21**	403	20	0.6737	0.0323	0.7060	64
1992	794	86	419	80	0.9495	0.3728	1.3223	121
1993	816	38	504	33	1.1421	0.1538	1.2959	118
1994	1038	56	695	49	1.2714	0.2793	1.5507	142
1995	1365	101	983	95	1.5115	0.5415	2.0530	187
1996	982	98	601	93	1.0414	0.5244	1.5658	143
1997	1300	77	783	72	1.3568	0.4060	1.7627	161
1998	766	128	541	125	0.9450	0.7048	1.6498	151
1999	1091	121	819	110	1.3629	0.6202	1.9831	181
Torrent River								
1984	1805	288	1,805	288	3.0902	0.9118	4.0020	270
1985	1623	30	1,551	30	2.3022	0.0909	2.3932	161
1986	3155	93	2,815	92	4.9539	0.3913	5.3452	360
1987	2670	68	2,482	68	2.7027	0.2486	2.9513	199
1988	2388	44	2,075	44	3.8292	0.1130	3.9422	266
1989	1512	60	1,367	60	3.1478	0.1874	3.3352	225
1990	2518	82	2,296	82	3.0851	0.1993	3.2843	221
1991	1591	71	1,440	71	2.4155	0.2295	2.6450	178
1992	2832	170	2,344	169	4.1125	0.5364	4.6489	313
1993	4215	224	4,009	222	7.2739	0.7046	7.9784	538
1994	3827	332	3,592	331	6.2796	1.5815	7.8611	530
1995	6168	615	5,800	611	12.4117	2.9193	15.3310	1033
1996	7371	509	6,923	507	16.4851	2.4955	18.9807	1279
1997	4033	674	3,659	666	8.7749	3.0607	11.8357	797
1998	5329	766	4,999	757	10.2389	3.4790	13.7178	924
1999	4330	411	4,008	399	8.2555	1.8337	10.0892	680
Western Arm Brook								
1984	235	0	117	0	0.2746	0.0000	0.2746	30
1985	**467**	1	416	1	0.7202	0.0017	0.7219	80
1986	**827**	0	525	0	1.4194	0.0000	1.4194	156
1987	437	1	378	1	0.9297	0.0025	0.9322	103
1988	**422**	1	251	1	0.6051	0.0024	0.6075	67
1989	**465**	0	455	0	1.2907	0.0000	1.2907	142
1990	**444**	0	444	0	1.4276	0.0000	1.4276	157
1991	233	1	233	1	0.6129	0.0026	0.6155	68
1992	480	8	480	8	1.3454	0.0224	1.3678	151
1993	947	8	947	8	2.5943	0.0219	2.6163	288
1994	954	31	954	31	2.5321	0.1187	2.6507	292
1995	823	33	796	30	2.3844	0.2122	2.5966	286
1996	1230	50	1,189	48	3.4858	0.2839	3.7696	415
1997	509	55	508	55	1.4985	0.3167	1.8152	200
1998	1718	128	1,650	128	4.9381	0.7337	5.6718	625
1999	1046	22	1,045	22	3.2205	0.1347	3.3552	370

Notes:

1. Lomond egg depositions in 1984-88 is based on 1983-93 mean biological characteristics and 1992-93 based on 1993 values.
2. Torrent egg depositions in 1990-93 based on 1985-89 mean biological characteristics for 1985-89 for small and large salmon.
3. Western Arm Brook egg depositions in 1984 based on 1974-93 mean biological characteristics for small and large salmon combined.

Table 7. Marine survival of Atlantic salmon smolts to returning adults at Western Arm Brook, 1971-1999.

Smolt Year (i)	Smolts Year (i)	Small Returns Year (i+1)			
		Small Returns Year (i+1)	% Virgin 1SW	V. 1SW Returns Year (i+1)	% Sea-Survival
1971	5735	406	95.9	389	6.8
1972	11905	797	99.6	794	6.7
1973	8484	506	100.0	506	6.0
1974	11854	639	100.0	639	5.4
1975	9600	552	100.0	552	5.8
1976	6232	373	100.0	373	6.0
1977	9899	315	97.7	308	3.1
1978	13071	1578	99.6	1572	12.0
1979	8349	465	100.0	465	5.6
1980	15665	492	97.0	477	3.0
1981	13981	467	100.0	467	3.3
1982	12477	1141	99.5	1135	9.1
1983	10552	235	100.0	235	2.2
1984	20653	467	98.8	462	2.2
1985	13417	527	100.0	527	3.9
1986	17719	437	100.0	437	2.5
1987	17029	422	84.1	355	2.1
1988	15321	455	100.0	455	3.0
1989	11407	444	97.9	435	3.8
1990	10563	233	100.0	233	2.2
1991	13453	480	99.8	479	3.6
1992	15405	947	86.3	817	5.3
1993	13435	954	96.3	919	6.8
1994	9283	823	100.0	823	8.9
1995	15144	1230	100.0	1230	8.1
1996	14502	509	84.3	429	3.0
1997	23845	1718	92.0	1581	6.6
1998	17139	1046	99.8	1044	6.1
1999	13500	1486	99.8	1483	11.0
2000	12691				
Mean (92-98)	15536	1032	94	978	6.4
95% CI +/-	4073	346	6	335	1.8
C.V.	28.3	36.3	7.1	37.0	30.2
N	7	7	7	7	7
Mean (84-91)	14945	433	98	423	2.9
95% CI +/-	2845	73	5	76	0.6
C.V.	22.8	20.1	5.6	21.4	26.3
N	8	8	8	8	8

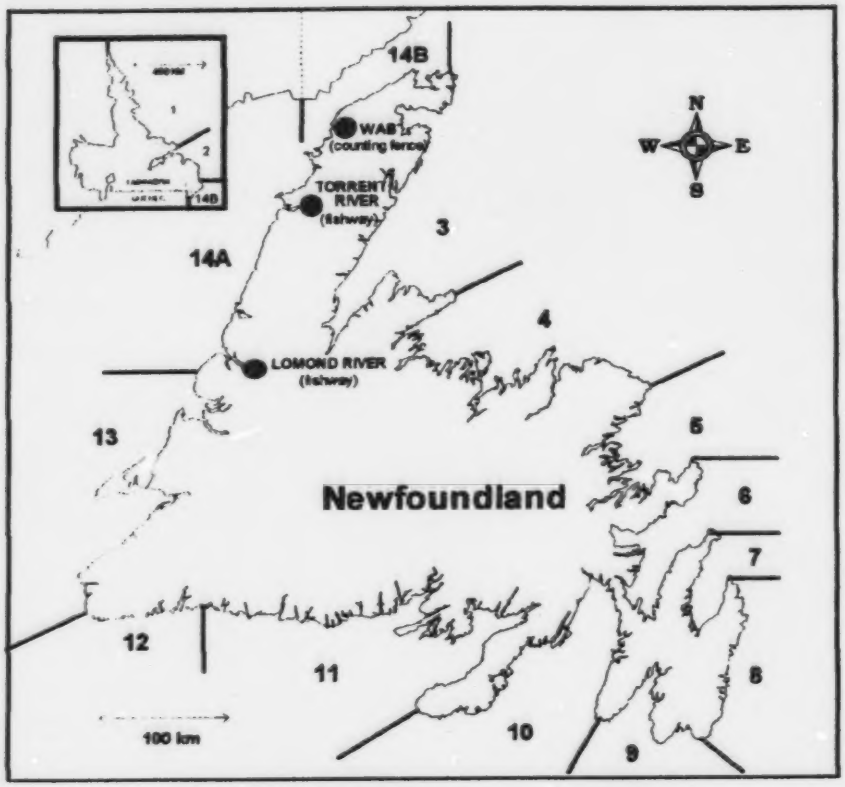
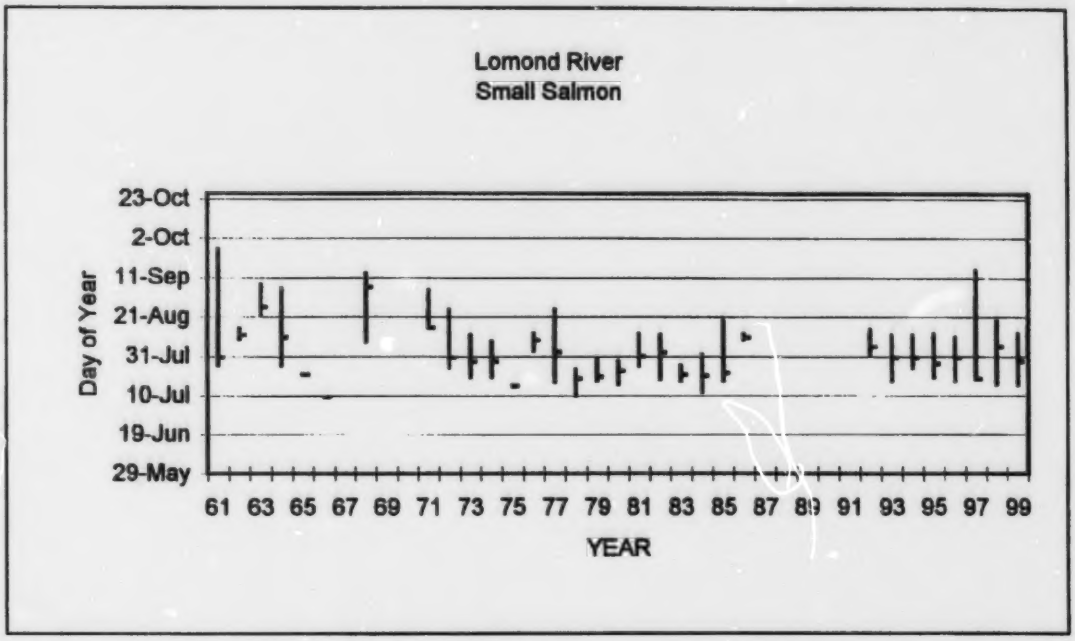


Figure 1. Salmon Fishing Areas (SFAs) of Newfoundland and Labrador.



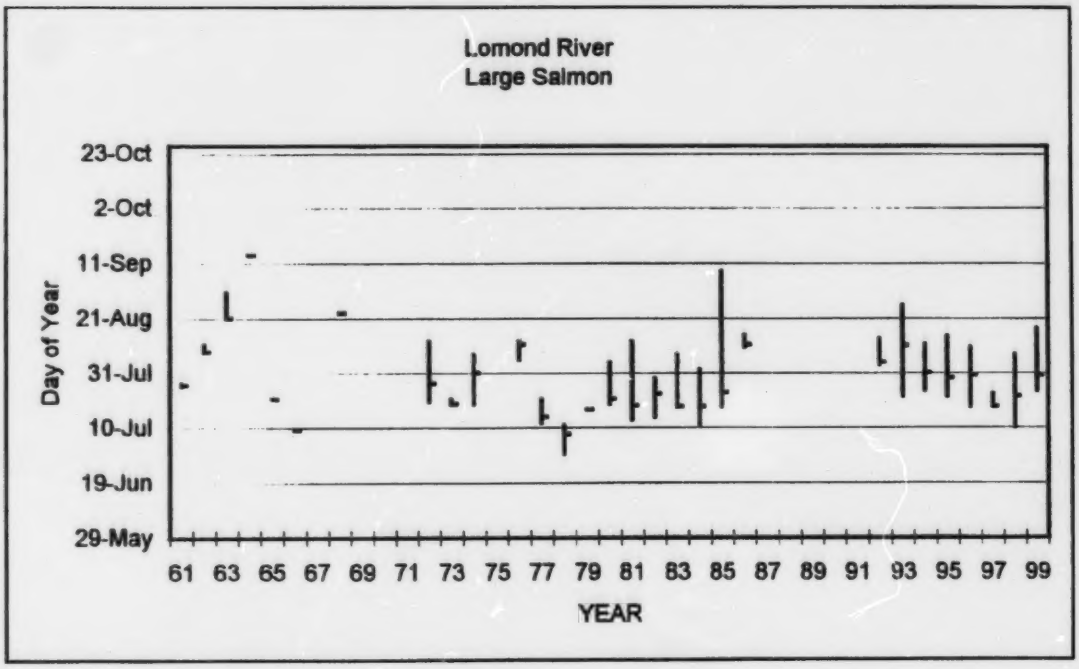
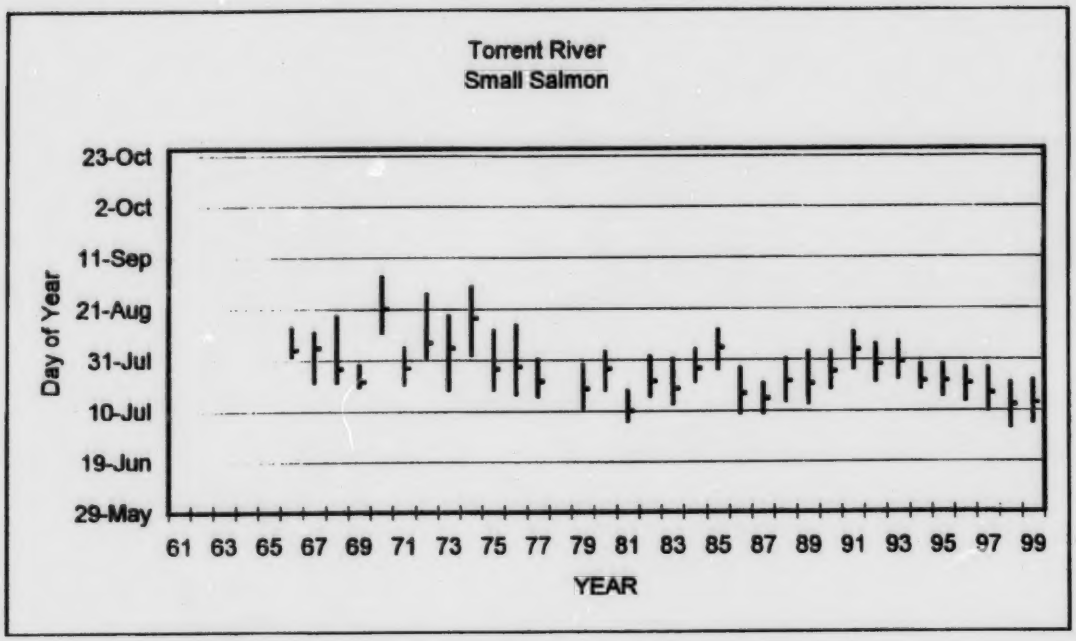


Figure 2. Run timing of small and large Atlantic salmon at Lomond River, 1961-1999. Vertical lines represent 25% to 75% of the run and marks represent 50% of the run.



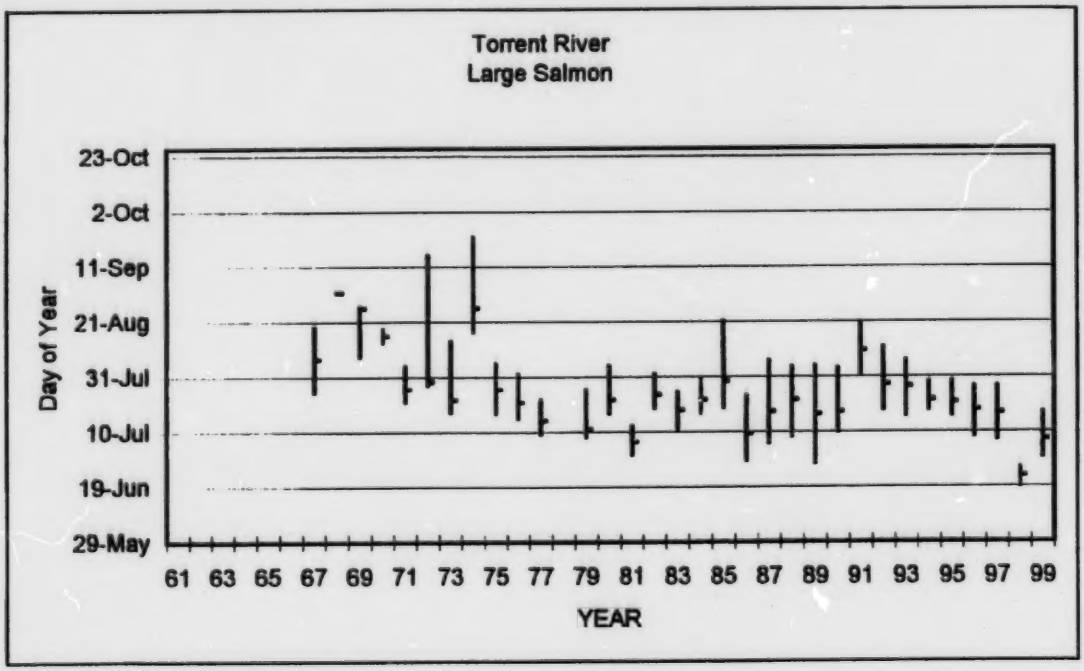
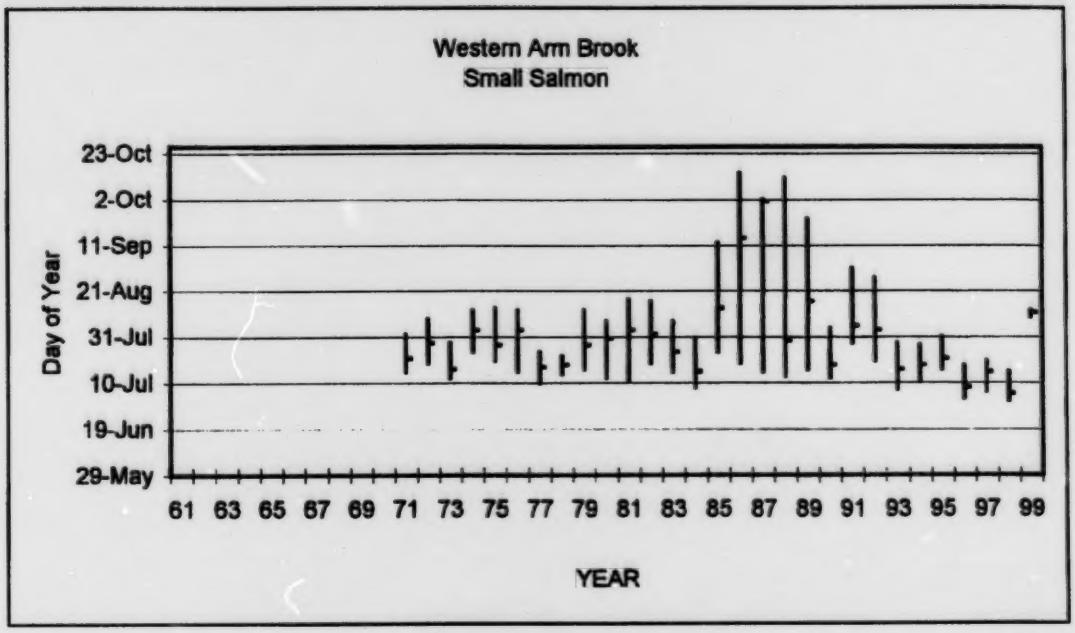


Figure 3. Run timing of small and large Atlantic salmon at Torrent River, 1961-1999. Vertical lines represent 25% to 75% of the run and marks represent 50% of the run.



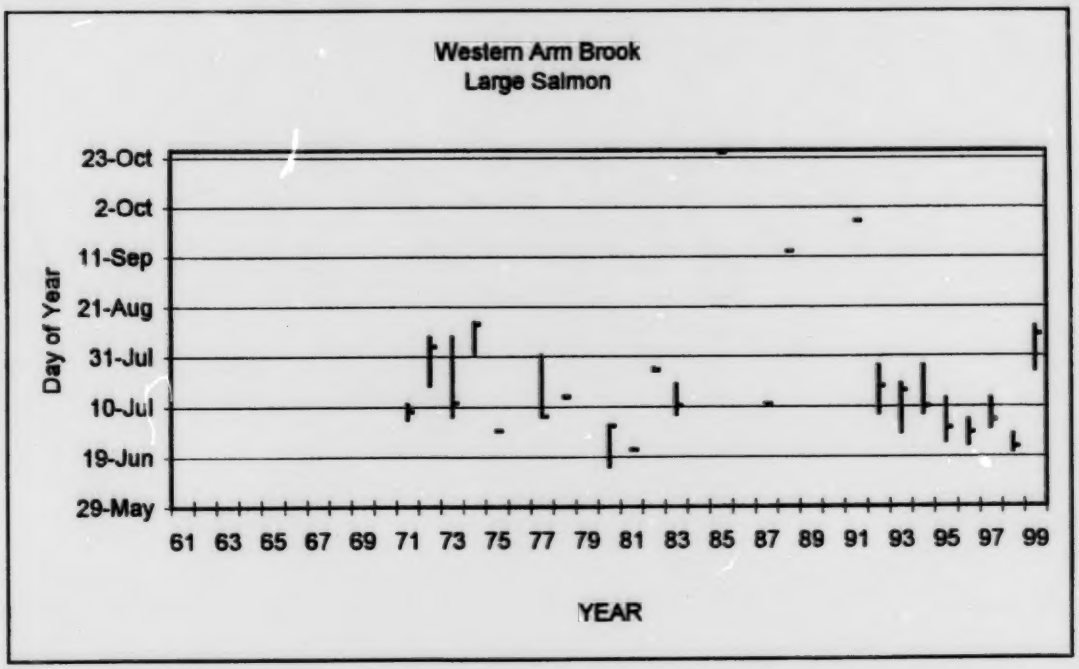


Figure 4. Run timing of small and large Atlantic salmon at Western Arm Brook, 1961-1999. Vertical lines represent 25% to 75% of the run and marks represent 50% of the run.

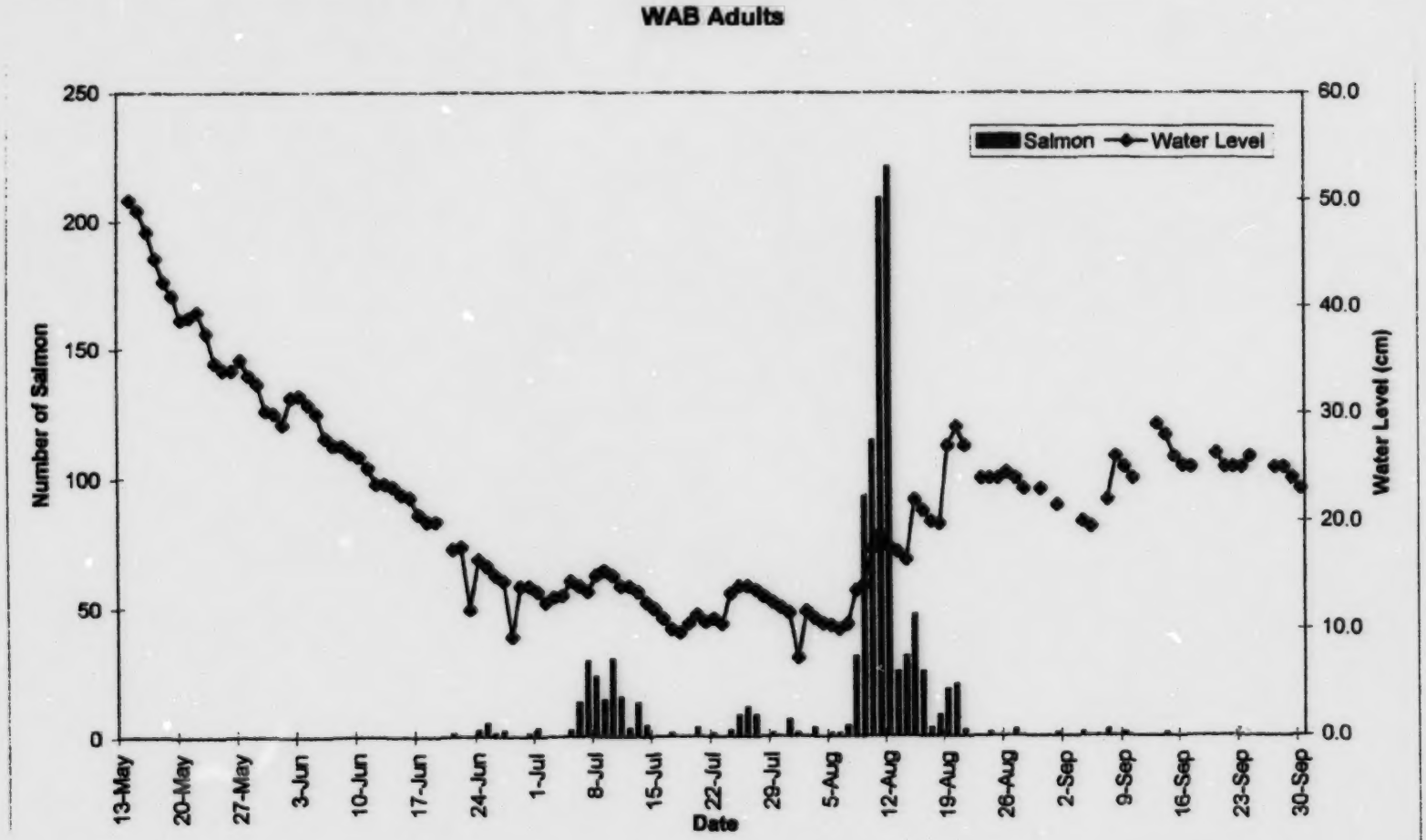


Figure 5. Daily counts of Atlantic salmon and mean water levels recorded at the Western Arm Brook counting fence, 1999.

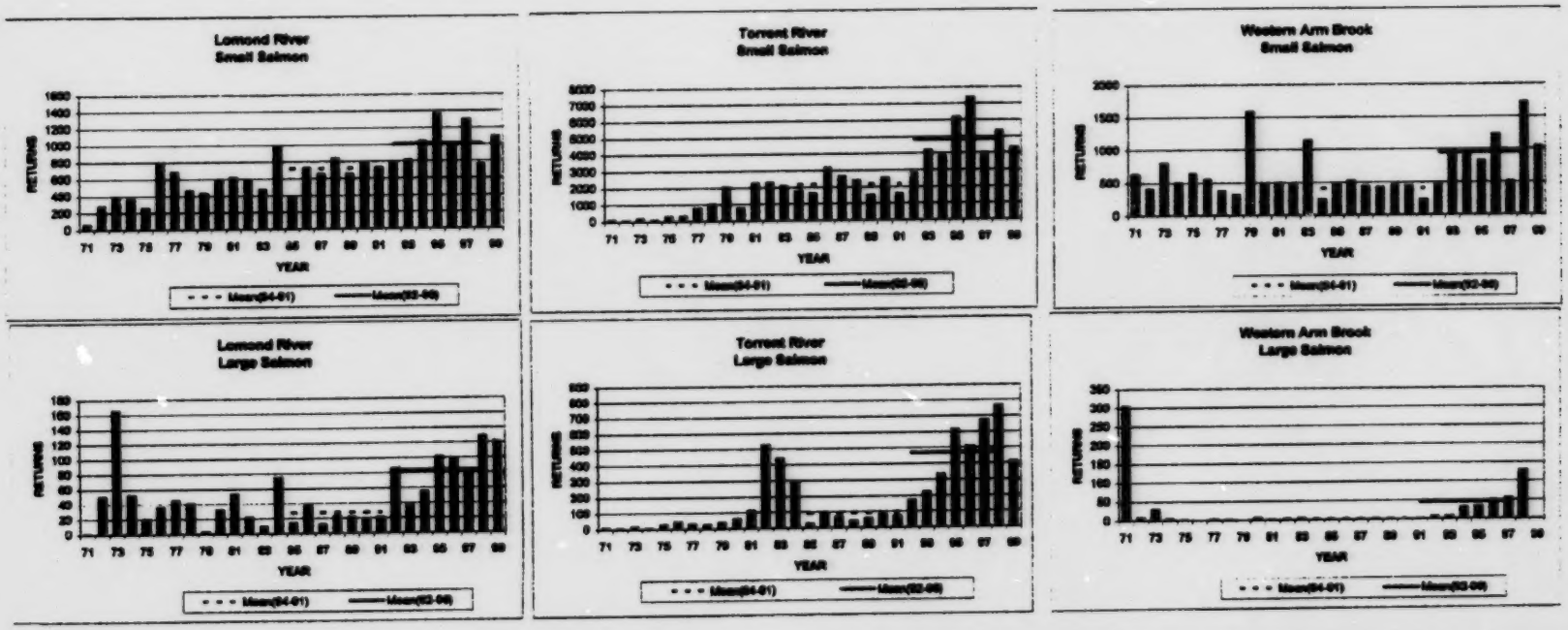


Figure 6. Returns of small and large Atlantic salmon to Lomond River, Torrent River and Western Arm Brook, 1971-1999. Dashed horizontal line represents the 1984-1991 mean and the solid horizontal line represents the 1992-1998 mean.

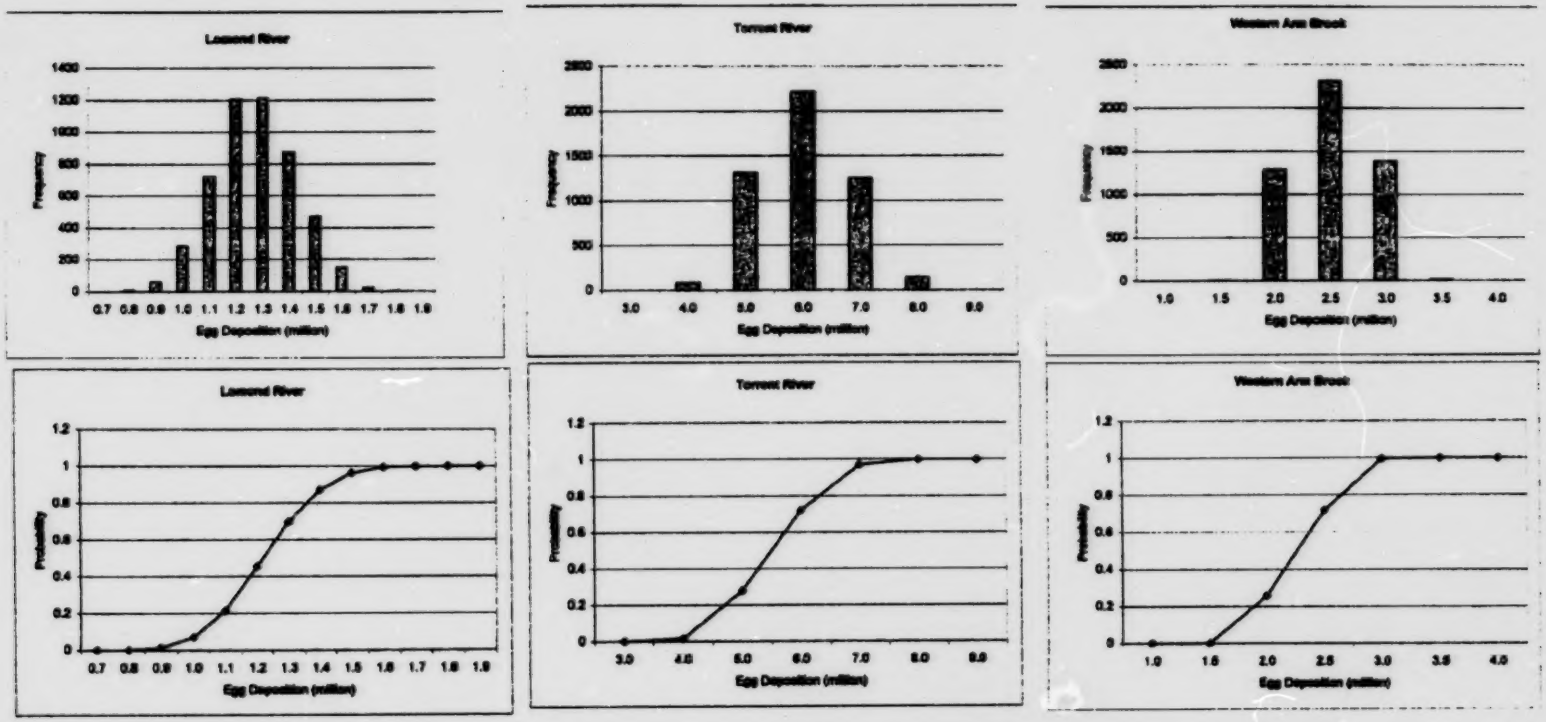


Figure 7. Frequency distribution and cumulative probability distribution of potential egg depositions calculated for Lomond River, Torrent River and Western Arm Brook, 1999.

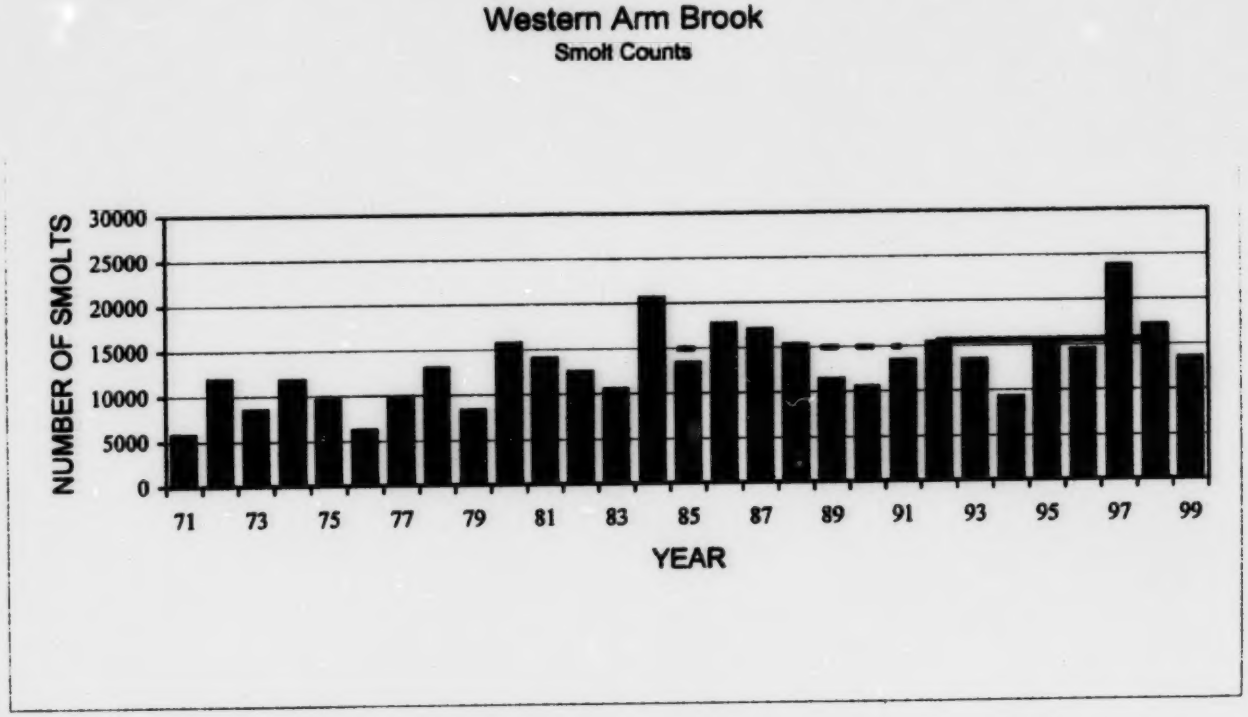


Figure 8. Counts of Atalntic salmon smolts at the counting fence on Western Arm Brook, 1971-1999. Dashed horizontal line represents the 1984-1991 mean and the solid horizintal line represents the 1991-1998 mean.

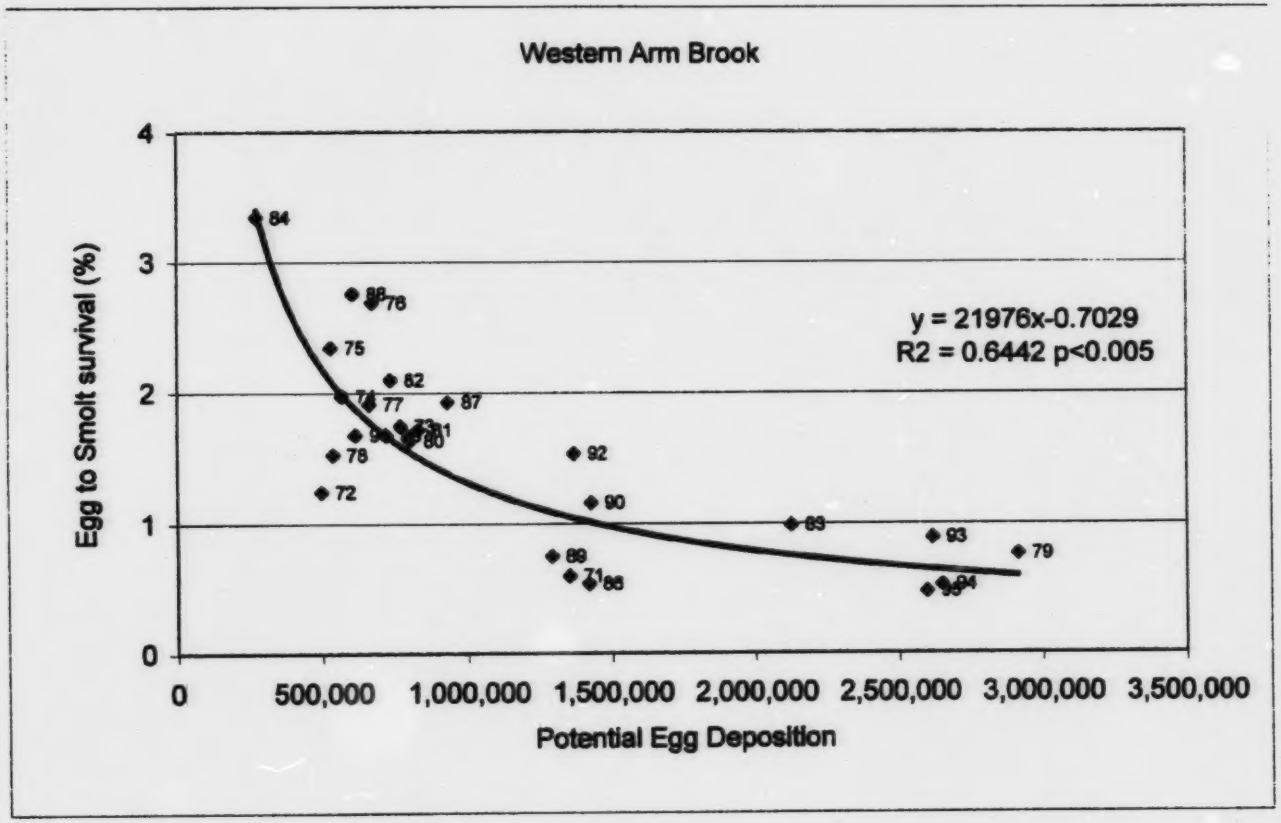


Figure 9. Variation in egg-to-smolt survival with changing egg deposition at Western Arm Brook. The 1994 year-class was complete to age-4 smolts in 1999.

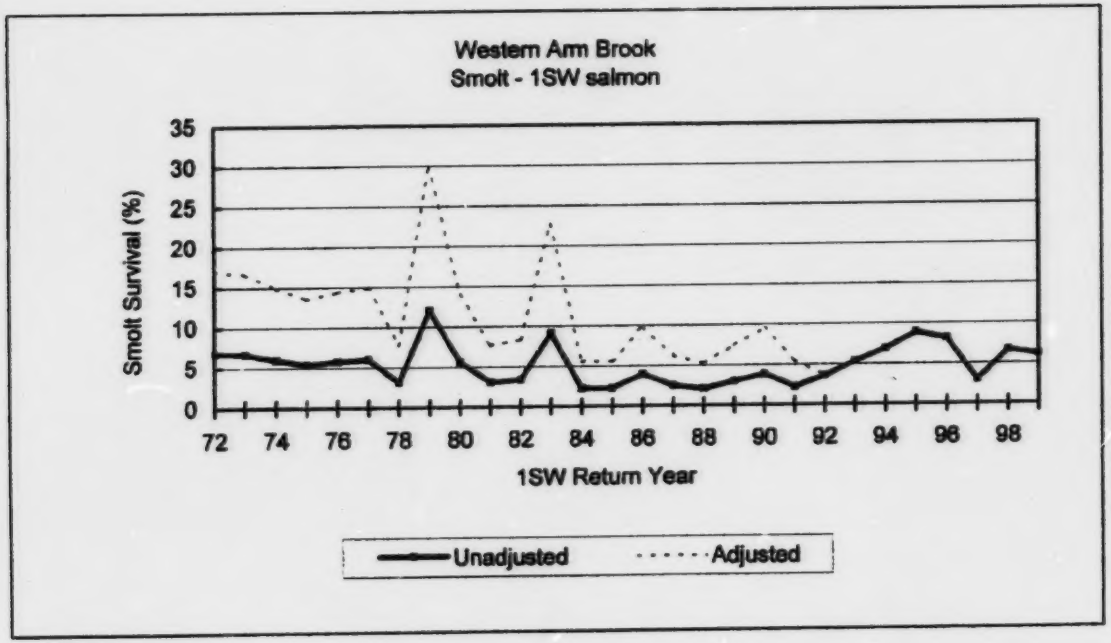


Figure 10. Annual variation in marine survival of Atlantic salmon smolts to one sea winter adults on Western Arm Brook, 1972-1999. Dashed line represents adjustment for commercial fishery removals.

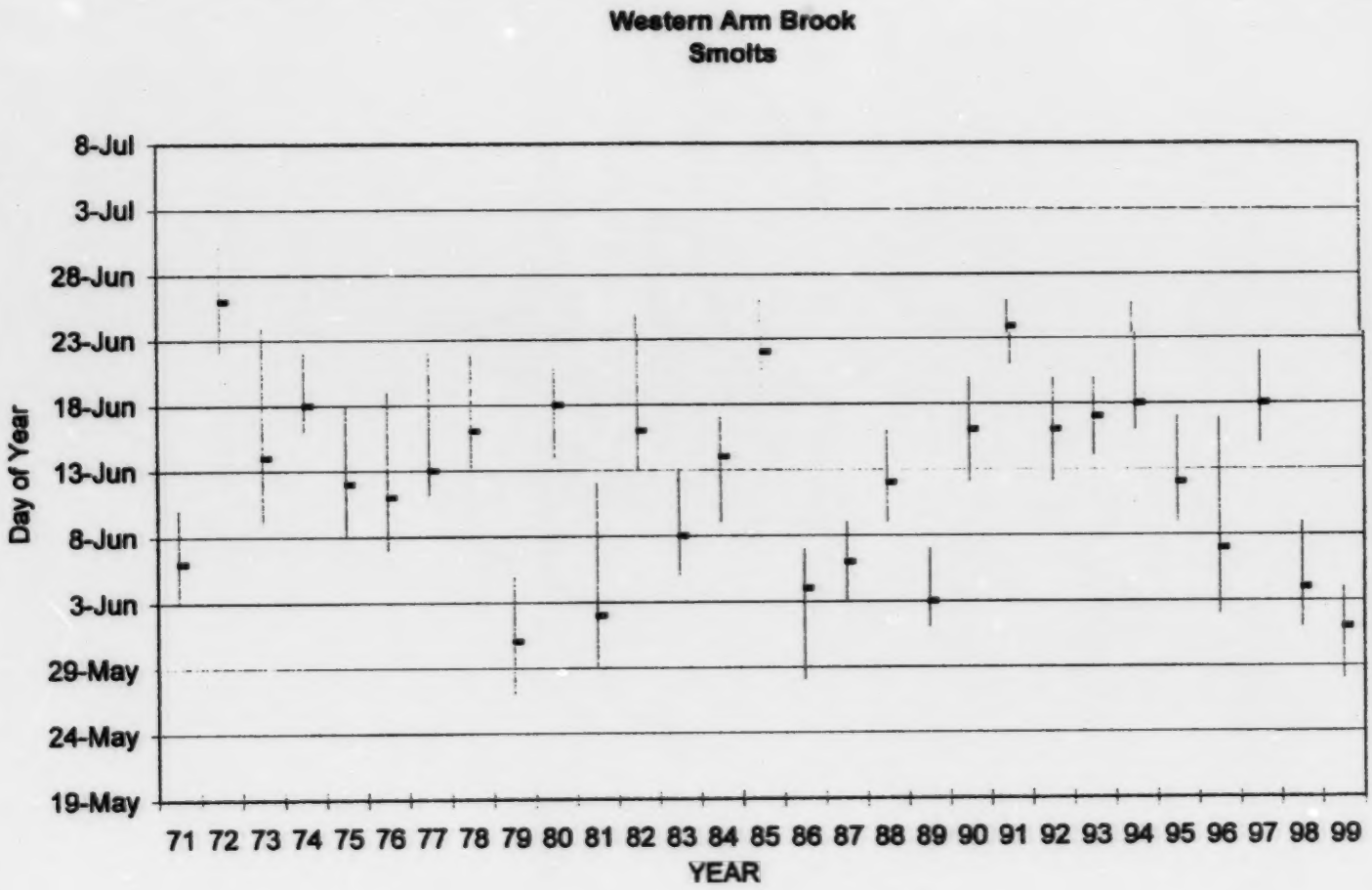


Figure 11. Run timing of Atlantic salmon smolts at Western Arm Brook, 1971-1999. Vertical lines represent 25% to 75% of the run and marks represent 50% of the run.

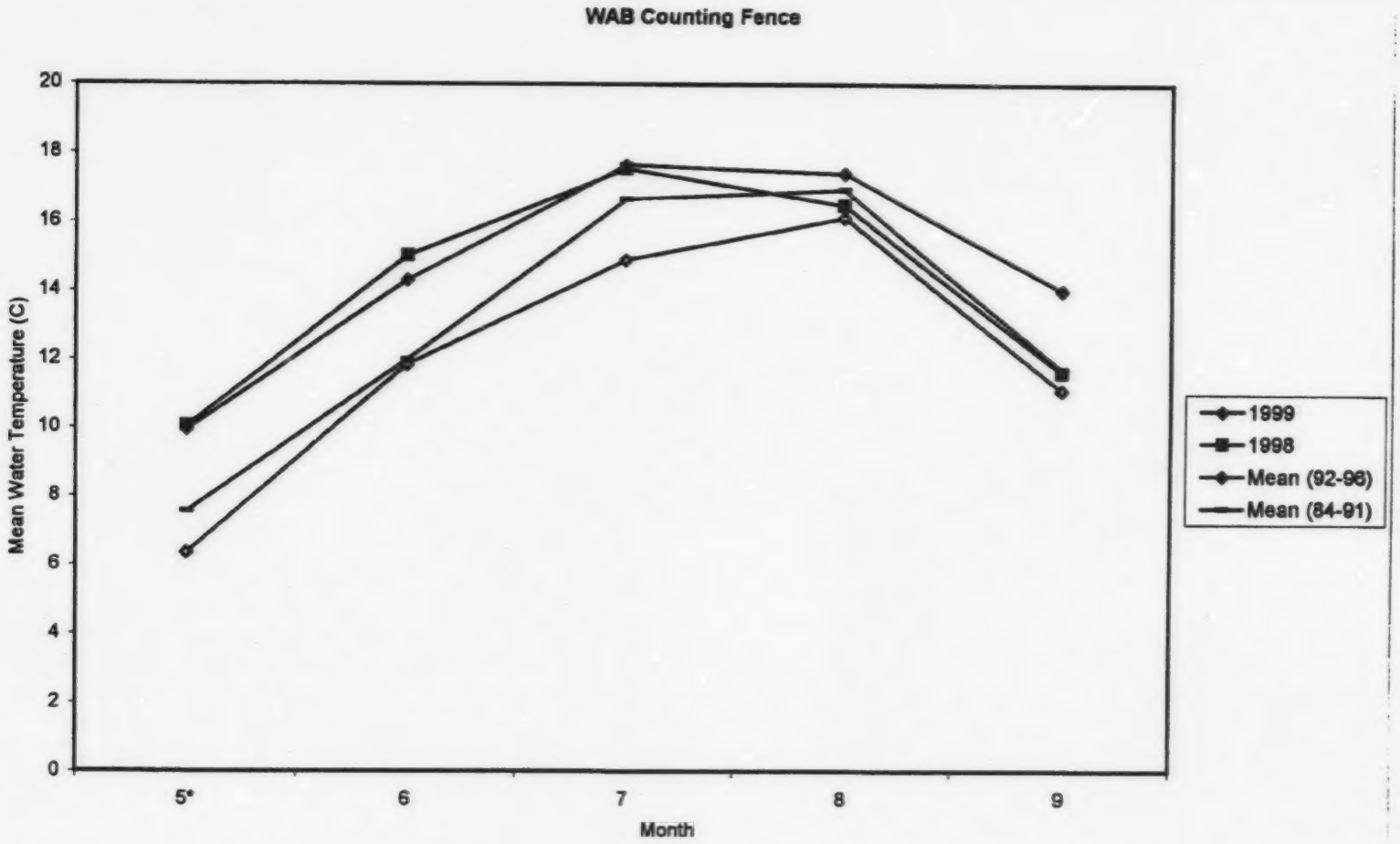


Figure 12. Mean monthly water temperature recorded at the counting fence on Western Arm Brook, 1984-1999. * Mean for May is May 20-31 except for 1995 from May 26-31.

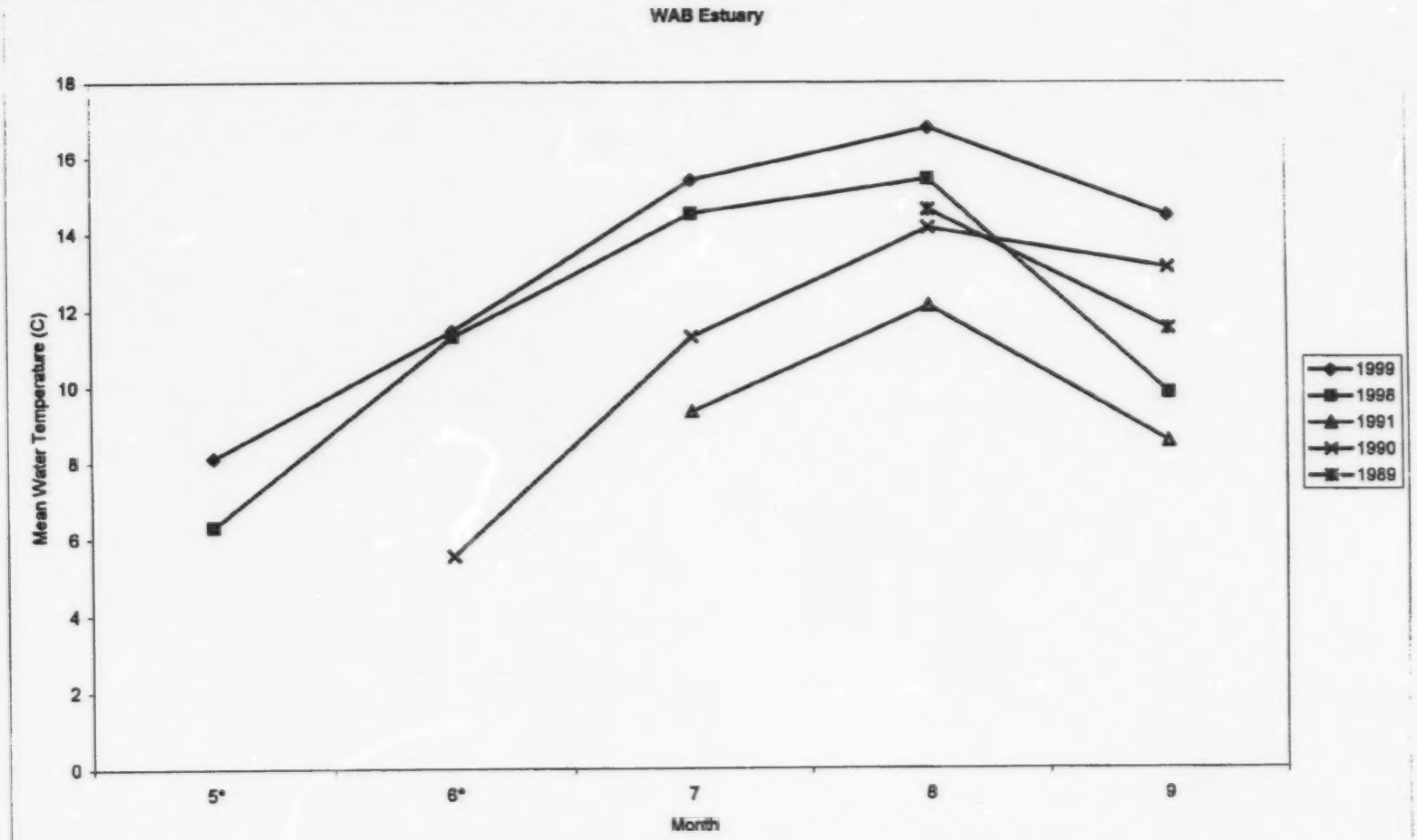


Figure 13. Mean monthly water temperature recorded in the estuary of Western Arm Brook, 1989-1999. Thermometer is located 2m off the bottom. * May temperatures were from May 20-31 and the June 1990 mean is from June 13-30.

Appendix 1. Recreational salmon fishery catch and effort data, 1974-1999.
River: Lomond River

Code: 4503820

	Effort	Small (<63 cm)			Large (>=63 cm)			Total (Small + Large)			
Year	Rod Days	Ret.	Rel.	Tot.	Ret.	Rel.	Tot.	Ret.	Rel.	Tot.	CPUE
1974	1331	324	.	324	19	.	19	343	.	343	0.26
1975	773	258	.	258	20	.	20	278	.	278	0.36
1976	2045	650	.	650	25	.	25	675	.	675	0.33
1977	1461	495	.	495	34	.	34	529	.	529	0.36
1978	1267	345	.	345	29	.	29	374	.	374	0.30
1979	900	235	.	235	2	.	2	237	.	237	0.26
1980	1218	293	.	293	13	.	13	306	.	306	0.25
1981	1446	507	.	507	3	.	3	510	.	510	0.35
1982	1435	308	.	308	7	.	7	315	.	315	0.22
1983	1112	251	.	251	3	.	3	254	.	254	0.23
1984	1505	546	.	546	28	.	28	574	.	574	0.38
1985	1075	203	.	203	*	2	2	203	2	205	0.19
1986	1164	371	.	371	*	46	46	371	46	417	0.36
1987	1186	297	.	297	*	12	12	297	12	309	0.26
1988	1545	404	.	404	*	25	25	404	25	429	0.28
1989	1714	270	.	270	*	5	5	270	5	275	0.16
1990	1938	386	.	386	*	17	17	386	17	403	0.21
1991	1591	328	.	328	*	10	10	328	10	338	0.21
1992	1612	357	24	381	*	56	56	357	80	437	0.27
1993	2190	281	85	366	*	40	40	281	125	406	0.19
1994	2017	325	116	441	*	58	58	325	174	499	0.25
1995	2043	343	190	533	*	62	62	343	252	595	0.29
1996	2702	371	99	470	*	49	49	371	148	519	0.19
1997**		490	273	763	*	52	52	490	325	815	
1998**		201	226	427	*	23	23	201	249	450	
1999**		253	93	346	*	83	83	253	176	429	
84-89 $\bar{X}$	1364.8	348.5	.	348.5	.	18.0	19.7	353.2	18.0	368.2	0.27
95% CL	269.8	126.5	.	126.5	.	22.3	17.4	136.3	22.3	138.7	0.10
N	6	6	0	6	0	5	6	6	5	6	6
86-91 $\bar{X}$	1523.0	342.7	.	342.7	.	19.2	19.2	342.7	19.2	361.8	0.24
95% CL	317.1	55.6	.	55.6	.	15.5	15.5	55.6	15.5	66.6	0.07
N	6	6	0	6	0	6	6	6	6	6	6
92-96 $\bar{X}$	2112.8	335.4	102.8	438.2	.	53.0	53.0	335.4	155.8	491.2	0.23
95% CL	488.0	43.3	74.3	84.4	.	10.8	10.8	43.3	79.3	91.7	0.06
N	5	5	5	5	0	5	5	5	5	5	5

IN THE ABOVE TABLE A PERIOD INDICATES NO DATA FOR THAT YEAR.
CPUE IS BASED ON RETAINED + RELEASED FISH FOR 1985 - 1996 AND ON RETAINED FISH ONLY PRIOR TO 1985.
* NOT ALLOWED TO RETAIN LARGE SALMON IN INSULAR NEWFOUNDLAND.
**DATA OBTAINED FROM THE LICENSE STUB RETURN, 1999 DATA ARE PRELIMINARY

Appendix 2. Recreational salmon fishery catch and effort data, 1974-1999.
River: Torrent River

Code: 4704600

	Effort	Small (<63 cm)			Large (>=63 cm)			Total (Small + Large)			
Year	Rod Days	Ret.	Rel.	Tot.	Ret.	Rel.	Tot.	Ret.	Rel.	Tot.	CPUE
1974	400	58	.	58	4	.	4	62	.	62	0.16
1975	364	123	.	123	6	.	6	129	.	129	0.35
1976	.	.	.	.	.	.	.	.	.	.	.
1977	.	.	.	.	.	.	.	.	.	.	.
1978	183	31	.	31	4	.	4	35	.	35	0.19
1979	238	65	.	65	3	.	3	68	.	68	0.29
1980	.	.	.	.	.	.	.	.	.	.	.
1981	656	167	.	167	18	.	18	185	.	185	0.28
1982	535	187	.	187	2	.	2	189	.	189	0.35
1983	354	82	.	82	1	.	1	83	.	83	0.23
1984	.	.	.	.	.	.	.	.	.	.	.
1985	251	70	.	70	*	0	0	70	0	70	0.28
1986	767	340	.	340	*	5	5	340	5	345	0.45
1987	576	165	.	165	*	1	1	165	1	166	0.29
1988	803	313	.	313	*	0	0	313	0	313	0.39
1989	559	143	.	143	*	0	0	143	0	143	0.26
1990	629	222	.	222	*	4	4	222	4	226	0.36
1991	438	150	.	150	*	1	1	150	1	151	0.34
1992	833	477	75	552	*	6	6	477	81	558	0.67
1993	619	179	266	445	*	15	15	179	281	460	0.74
1994	992	227	82	309	*	9	9	227	91	318	0.32
1995	1816	331	369	700	*	36	36	331	405	736	0.41
1996	2027	421	270	691	*	20	20	421	290	711	0.35
1997**		327	469	796	*	79	79	327	548	875	
1998**		275	552	827	*	89	89	275	641	916	
1999**		293	293	586	*	120	120	293	413	706	
84-89 $\bar{X}$	591.2	206.2	.	206.2	.	1.2	1.2	206.2	1.2	207.4	0.35
95% CL	272.5	143.6	.	143.6	.	2.7	2.7	143.6	2.7	145.3	0.11
N	5	5	0	5	0	5	5	5	5	5	5
86-91 $\bar{X}$	628.7	222.2	.	222.2	.	1.8	1.8	222.2	1.8	224.0	0.36
95% CL	143.5	90.1	.	90.1	.	2.2	2.2	90.1	2.2	91.3	0.08
N	6	6	0	6	0	6	6	6	6	6	6
92-96 $\bar{X}$	1257.4	327.0	212.4	539.4	.	17.2	17.2	327.0	229.6	556.6	0.44
95% CL	775.9	156.1	160.2	206.7	.	14.7	14.7	156.1	173.7	217.1	0.17
N	5	5	5	5	0	5	5	5	5	5	5

IN THE ABOVE TABLE A PERIOD INDICATES NO DATA FOR THAT YEAR.
CPUE IS BASED ON RETAINED + RELEASED FISH FOR 1985 - 1996 AND ON RETAINED FISH ONLY PRIOR TO 1985.
* NOT ALLOWED TO RETAIN LARGE SALMON IN INSULAR NEWFOUNDLAND.
**DATA OBTAINED FROM THE LICENSE STUB RETURN; 1999 DATA ARE PRELIMINARY

Appendix 3. Recreational salmon fishery catch and effort data, 1974-1999.
River: West River (Western Arm Brook)

Code: 4905190

Year	Effort	Small (<63 cm)			Large (>=63 cm)			Total (Small + Large)			
	Rod Days	Ret.	Rel.	Tot.	Ret.	Rel.	Tot.	Ret.	Rel.	Tot.	CPUE
1974	361	124	.	124	0	.	0	124	.	124	0.34
1975	155	8	.	8	0	.	0	8	.	8	0.05
1976	115	32	.	32	0	.	0	32	.	32	0.28
1977	107	11	.	11	0	.	0	11	.	11	0.10
1978	168	22	.	22	1	.	1	23	.	23	0.14
1979	5	0	.	0	0	.	0	0	.	0	0.00
1980	175	30	.	30	2	.	2	32	.	32	0.18
1981	209	41	.	41	0	.	0	41	.	41	0.20
1982	379	73	.	73	0	.	0	73	.	73	0.19
1983	15	0	.	0	0	.	0	0	.	0	0.00
1984	432	115	.	115	0	.	0	115	.	115	0.27
1985	204	46	.	46	*	0	0	46	0	46	0.23
1986	.	.	.	.	*	.	.	.	.	.	.
1987	269	59	.	59	*	2	2	59	2	61	0.23
1988	701	171	.	171	*	0	0	171	0	171	0.24
1989	.	.	.	.	*	.	.	.	.	.	.
1990	.	.	.	.	*	.	.	.	.	.	.
1991	.	.	.	.	*	.	.	.	.	.	.
1992	.	.	.	.	*	.	.	.	.	.	.
1993	.	.	.	.	*	.	.	.	.	.	.
1994	.	.	.	.	*	.	.	.	.	.	.
1995	.	.	.	.	*	.	.	.	.	.	.
1996	.	.	.	.	*	.	.	.	.	.	.
1997**	.	.	.	.	*	.	.	.	.	.	.
1998**	.	.	.	.	*	.	.	.	.	.	.
1999**	.	.	.	.	*	.	.	.	.	.	.
84-89 $\bar{X}$	401.5	97.8	.	97.8	.	0.7	0.5	97.8	0.7	98.3	0.24
95% CL	406.9	105.2	.	105.2	.	3.5	1.8	105.2	3.5	104.4	0.03
N	4	4	0	4	0	3	4	4	3	4	4
86-91 $\bar{X}$	485.0	115.0	.	115.0	.	1.0	1.0	115.0	1.0	116.0	0.24
95% CL	3881.3	1006.3	.	1006.3	.	18.0	18.0	1006.3	18.0	988.3	0.09
N	2	2	0	2	0	2	2	2	2	2	2
92-96 $\bar{X}$	0.0	0.0	0.0	0.0	.	0.0	0.0	0.0	0.0	0.0	0.00
95% CL	0.0	0.0	0.0	0.0	.	0.0	0.0	0.0	0.0	0.0	0.00
N	5	5	5	5	0	5	5	5	5	5	5

IN THE ABOVE TABLE A PERIOD INDICATES NO DATA FOR THAT YEAR.
CPUE IS BASED ON RETAINED + RELEASED FISH FOR 1985 - 1998 AND ON RETAINED FISH ONLY PRIOR TO 1985.
* NOT ALLOWED TO RETAIN LARGE SALMON IN INSULAR NEWFOUNDLAND.
**DATA OBTAINED FROM THE LICENSE STUB RETURN; 1999 DATA ARE PRELIMINARY